

# INITIAL EFFECTS OF PRESCRIBED BURNING ON SURVIVAL AND NESTING SUCCESS OF NORTHERN BOBWHITES IN WEST-CENTRAL TEXAS

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## ABSTRACT

Fire is often prescribed for managing habitat for northern bobwhites (*Colinus virginianus*) in the southeastern United States, yet little is known about its use as a tool in more xeric portions of the species' range. This study was conducted from 1994 to 1995 on 3 sites in the northern Edwards Plateau ecoregion of Texas to monitor immediate post-burn effects on bobwhite ecology. Each site included a burned pasture paired with an unburned control. We radiomarked  $\geq 50$  bobwhites (25/pasture) at each study site with neck-loop transmitters just prior to burning and monitored their survival and nesting habits for 6 months post-burn. Survival was similar ( $P > 0.05$ ) between burned and unburned areas. Predation was the leading cause of mortality, with mammals and raptors accounting for 68% and 31% of the predation, respectively. Nest initiation and success were low for both treatments. Nest sites occurred mostly in association with prickly pear cactus (*Opuntia* spp.). Our results suggest that relatively "cool" prescribed burns had few short-term effects on bobwhite survival in west-central Texas. However, reductions in cacti density and cover that often occur post-burn, especially if followed by an application of herbicide (i.e., picloram), may reduce the number of potential nesting sites for bobwhites.

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**Key words:** burning, cacti, *Colinus virginianus*, mortality, nesting, northern bobwhite, prickly pear, range management, telemetry, Texas

## INTRODUCTION

Prescribed burning is a tool to improve northern bobwhite (*Colinus virginianus*) habitat throughout the southeastern United States. Additionally, fire has become an important tool for managing rangelands throughout the Great Plains (Wright and Bailey 1982: 91). Burning is a relatively inexpensive technique for increasing forage availability for livestock and wildlife while controlling less desirable species like juniper (*Juniperus* spp.) and cacti (*Opuntia* spp.) (White and Hanselka 1989).

The impacts of burning on bobwhite habitat are unclear. Late winter burning improves bobwhite habitat in southern pine forests (Stoddard 1931:402, Speake 1967, Rosene 1969:293) and in the midwest (Ellis et al. 1969, Seitz and Landers 1972). Conversely, there is some evidence that bobwhites prefer to nest in unburned locations with adequate perennial bunchgrass cover (Rosene 1969:198, Dimmick 1971). Because the western range of bobwhites is more xeric (<40 cm annual precipitation in west Texas versus >120 cm in Florida), the impacts of fire on bobwhite

habitat may be less beneficial. Good nesting habitat typically consists of bunchgrasses that are several years old with a large overhead canopy (e.g., little bluestem [*Schizachyrium scoparium*]) (Lehmann 1984: 81, Townsend et al. 2001); fire typically consumes such vegetation.

Predators are the major causes of bobwhite mortality and nest failure (Stoddard 1931:187, Hurst et al. 1996, Rollins and Carroll 2001). Rollins and Carroll (2001) reported an average hatch rate of 28% across the range of published studies of bobwhites; mesomammals (e.g., *Procyon lotor*, *Mephitis mephitis*) commonly depredate quail nests (Hernández et al. 1997). Raptors are also major predators of juvenile and adult bobwhites (Stoddard 1931:211, Mueller 1988). In northern Florida, raptors (primarily accipiters) were responsible for 60% of the annual predation of bobwhites (DeVos 1985). Almost 50% of the annual bobwhite mortality on the Tall Timbers Research Station in Florida occurs in February through April when raptors are localized in the region.

Prescribed burning may increase the vulnerability of bobwhites to predators (especially raptors) via reductions in escape cover (Mueller and Atkinson 1985; Guthery 2000:69). Likewise, the reduction of peren-

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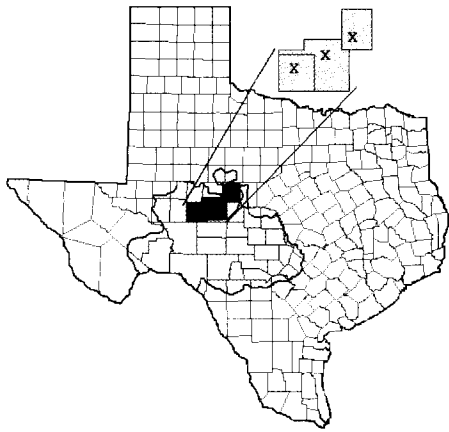


Fig. 1. Study sites located in (left to right in inset) Irion, Tom Green, and Runnels counties, Texas. Each county is located on the northwestern edge of the Edwards Plateau ecoregion. Approximate study location within each county indicated by an "X".

nial bunchgrasses and prickly pear may reduce nesting success (Slater et al. 2001). Accordingly, we designed a study to (1) monitor post-burn survival and cause-specific mortality of bobwhites and (2) monitor nest site selection and nesting success on burned versus unburned sites in west-central Texas.

## METHODS

### Study Areas

We conducted our study during 1994–95 on 3 sites in the northern Edwards Plateau ecoregion of Texas in Irion, Tom Green, and Runnels counties (Fig. 1). Each study site consisted of a burned and unburned pasture located within 5 km of each other. Vegetation, soil type, and precipitation were similar within a particular study site, but varied somewhat across the 3 sites.

Site 1 was located in Irion County about 32 km west of San Angelo, Texas on the Funk Ranch. Average annual precipitation is 46 cm. Understory vegetation consisted primarily of cacti, three-awns (*Aristida* spp.), tobosa (*Hilaria mutica*), curlymesquite (*H. belangeri*) and buffalograss (*Buchloe dactyloides*). Overstory consisted of a mix of several small trees and shrubs, primarily mesquite (*Prosopis glandulosa*) and redberry juniper (*Juniperus pinchotii*). The burned site included 60 ha that was surrounded by the unburned site. Unburned areas were grazed with cattle, sheep, and goats at a heavy stocking rate (approximately 10 ha/animal unit [AU]). Predator control was conducted on this site for ranch management purposes (i.e., protection of sheep and goats). Predator species targeted for control were foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), and raccoon.

Site 2 was located on the north shore of O.C. Fisher Reservoir on the Angelo State University Management, Instruction, and Research (MIR) Center about 15 km northwest of San Angelo. Mean annual precipitation is 52 cm. Understory vegetation consisted of cacti, Texas wintergrass (*Stipa leucotricha*), Johnsongrass (*Sorghum halepense*), sideoats grama (*Bouteloua*

*curtipendula*), and threeawns. Overstory vegetation was primarily dominated by mesquite. The burned area consisted of 60 ha and the unburned area was several pastures surrounding the burn but at least 1.6 km from the burn. Unburned areas were grazed with cattle, sheep, and goats at moderate stocking rates (approximately 15 ha/AU).

Site 3 was located 8 km east of Bronte, Texas on the Tidwell and Rocking Horse Ranches. Average annual precipitation is 56 cm. Dominant understory vegetation consisted of Texas wintergrass, sideoats grama, threeawns, and cacti. The dominant overstory vegetation was mesquite. The burned pasture was 284 ha, whereas the adjacent unburned area was 130 ha.

Burn dates were 27 January 1994, 27 February 1994, and 13 January 1995 for sites 1–3, respectively. Burns were conducted under prescriptions according to Natural Resource Conservation Service guidelines (United States Department of Agriculture 1988). Fine fuel loads were estimated at 2,500, 4,000, and 3,500 kg/ha for sites 1–3, respectively. Fuel continuity was greatest at Site 2, and similar between sites 1 and 3. Headfires were ignited between 1300 and 1600 hours. Weather conditions (relative humidity, air speed, ambient temperature) varied across the 3 burns. Weather conditions (i.e., lower humidity, higher wind speeds) resulted in a "hotter" burn at site 2. Higher humidity prevailed at site 1, with site 3 being intermediate.

### Data Collection

We trapped bobwhites with standard Stoddard funnel-type traps (Day et al. 1980), 1–14 days prior to each burn. After capture, we fitted bobwhites with neck-loop radio telemeters weighing <6 g (Wildlife Materials, Inc.<sup>TM</sup>, Carbondale, Illinois, USA). We monitored bobwhite movements and survival thrice weekly prior to the burn, continuously throughout the burn, and immediately thereafter for 4–6 hours (Curtis et al. 1988). Post-burn monitoring occurred thrice weekly through May or until nest incubation was initiated. We then monitored bobwhites twice weekly for the remainder of the study (September of the burn year).

Cause-specific mortality was determined by examining the collar and other physical evidence at the kill site. We assumed a bobwhite was dead or incubating a nest when no fluctuation in the bird's daily location was detected. We classified the cause of mortality by inspecting kill sites. The main difference between a mammal and raptor kill is that a raptor leaves the bones and wings intact while mammals leave nothing but feathers (S. Cox, Oklahoma Department Wildlife Conservation, personal communication). The telemeter may also be used as evidence. A mammal leaves indentations on the softer parts of the telemeter, whereas a raptor typically leaves crimped marks on the antenna or the antenna is curled.

We inspected nest sites when incubation was suspected. When we located the nest, we placed an additional telemeter nearby to aid us in finding the nest in the absence of the incubating quail. We character-

Table 1. Sex and number of bobwhites radiomarked at 3 sites in west-central Texas, 1994–95.

Site	County	1994		1995	
		Males	Females	Males	Females
1	Irion	0	59		
2	Tom Green	21	35		
3	Runnels			45	51

ized nesting microhabitat relative to vegetative cover, number of eggs, and nest status when the hen was found to be away from the nest.

#### Data Analysis

We compared survivorship curves using the Kaplan-Meier survival estimator (Kaplan and Meier 1958) using the program STAGKAM (Kulowiec 1989), with the staggered entry approach (Pollock et al. 1989a). Survival distributions were compared using log-rank chi-square tests (Burger et al. 1991). We assumed that birds were sampled randomly and that trapping, handling, and radiomarking did not affect survival probability (Heisey and Fuller 1985, Burger et al. 1995) or cause-specific mortality agents. Bobwhites that died or were lost within 7 days of marking were excluded from the study (Kurzejeski et al. 1987, Pollock et al. 1989a,b). Bobwhites that were lost due to dispersal or radio failure were deemed "censored" (Pollock et al. 1989a). We used censored birds for survival probabilities up until the day the signal was lost, but they were not considered mortalities (Burger et al. 1995).

## RESULTS

#### Capture Success

We radiomarked 211 bobwhites across the 3 study sites (Table 1). Fifty-nine females were radiomarked at site 1: 28 from the burned plot and 31 from the unburned plot. Fifty-six birds were marked at site 2: 29 from the burned plot and 27 from unburned sites. Both females and males were marked at site 2 because of limited success of trapping females. The sample from the burned plot consisted of 15 females and 12 males, whereas the unburned plot included 20 females and 9 males. Site 3 included 57 (30 females, 27 males) on the burned plot and 39 (21 females, 18 males) on the unburned plot. Bobwhites on the burned area at site 3 were radiomarked during 2 separate trappings. Thirty-eight quail were radiomarked during January and 16 more during February. The additional collaring period was needed because a large number of the original birds died or were censored early in the study.

#### Survival

Across all 3 sites, 30 (14.2%) of the quail were excluded from the analysis because they did not survive or were censored within 7 days of radiomarking (Fig. 2). Twenty five (11.8%) of the remaining 181 quail were censored because of radio failure and 25

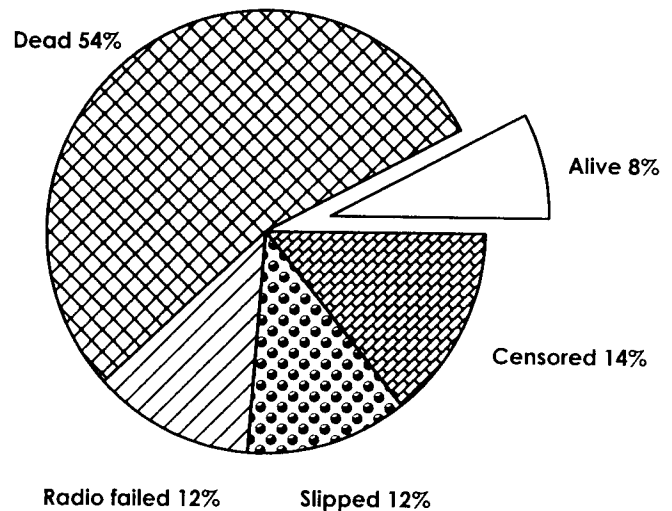


Fig. 2. Fates of radiomarked bobwhites at 3 study sites in west-central Texas, 1994–95.

(11.8%) slipped their transmitters. Seventeen (8.1%) quail survived throughout the study, leaving 114 (54.0%) that were killed.

Survival did not differ between treatments ( $P = 0.72$ ), among sites ( $P = 0.38$ ), or between age classes ( $P = 0.82$ ). We accepted the null hypothesis that survival rates were similar between burned and unburned areas. Females lived longer ( $P < 0.05$ ) than males across all sites. Females lived an average of  $72.2 \pm 7.7$  days, whereas males lived  $48.7 \pm 7.7$  days. Radiomarked birds lived an average of  $69.5 \pm 7.5$  days on site 1,  $67.9 \pm 7.7$  days on site 2, and  $55.3 \pm 7.1$  days on site 3.

No radiomarked bobwhites were killed directly as a result of the fire itself. Birds avoided the advancing flames by either moving ahead of, or flying over, the headfire.

Predation was the primary cause of post-burn mortality, accounting for 93 (82% of the total) deaths (Fig. 3). Mammals were credited with 63 deaths (55%), raptors with 29 deaths (25%), and snakes with 1 death. Seventeen (15%) radiomarked bobwhites died from unknown causes and 4 (4%) died from exposure immediately following a hail storm.

#### Nesting Ecology

Of the 58 radiomarked bobwhites (44 females and 14 males) alive at the onset of nesting (i.e., 1 May), 19 females incubated a total of 21 nests from May through September. Thirteen nests were located in unburned areas and 8 in burned areas ( $P = 0.25$ ). The null hypothesis of equal nesting in burned and unburned sites was accepted. Nesting success was similar on burned and unburned sites. Eight nests were successful, 9 were abandoned, and 4 were depredated.

Bobwhites chose 3 microhabitats for nesting: grass, brush-grass, and cacti associations (Table 2). Overall, 5 birds nested in grass, 4 in brush-grass, and 12 in cacti associations. On burned sites, 7 nests were in cacti associations and 1 in brush-grass. On un-

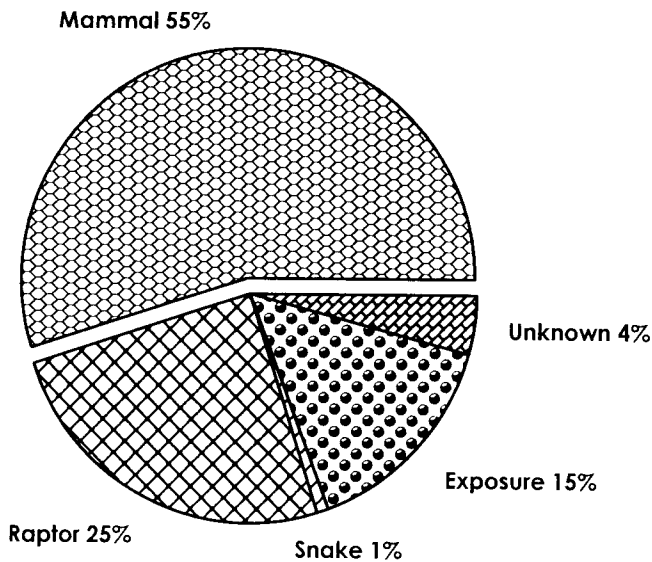


Fig. 3. Cause-specific mortality of radiomarked bobwhites from 3 study sites in west-central Texas, 1994–95.

burned sites, 5 nests were in grass, 5 in cacti associations, and 3 in brush–grass. Vegetation type chosen for nesting site did not affect nest success ( $P > 0.05$ ).

## DISCUSSION

### Survival

Similar survival rates of radiomarked bobwhites between burned and unburned sites suggested that prescribed burning had no effect on short-term survival rates under the conditions of this study. Northern harriers (*Circus cyaneus*) were observed flying over burned areas on several occasions during the burns, but no radiomarked quail were killed during, or immediately after, burning. Raptor predation on bobwhites has been documented during and immediately following burning in south Texas (Tewes 1984) and in northern Florida (Mueller and Atkinson 1985).

Mean survival rate from March–August in this study was 64.2 days, slightly lower than the mean of 70.7 days reported by Hernández (1999) in Shackelford County, Texas (about 150 km northeast of our study sites). His study sites in Shackelford County would generally be considered superior bobwhite habitat relative to our study sites (i.e., greater abundance of nesting cover and lighter stocking rates).

Predation was the major cause of death during this study, in concurrence with other studies of bobwhite mortality (Stoddard 1931:203, DeVos 1985, Mueller 1988, Burger et al. 1995, Hernández 1999, Rollins and Carroll 2001). Raptors are reported as the most serious predator of bobwhites in the southeastern United States (DeVos 1985, Mueller 1988), but mammals were responsible for most of the predation in this study (68%). We believe that gray foxes and feral cats were the primary mammalian predators, although red foxes, skunks, raccoons, bobcats, and ringtails (*Bassariscus astutus*) may have contributed to predation losses. Gray foxes would sometimes leave scat at kill sites

Table 2. Nesting location and nest fate of 21 bobwhite nests on burned versus unburned sites in west-central Texas, 1994–95.

Site	Treatment	Nest Location <sup>a</sup>	Microhabitat	Fate
1	Unburned	Unburned	Cacti/grass	Abandoned
	Unburned	Unburned	Cacti/grass	Depredated
	Unburned	Unburned	Brush/grass	Hatched
	Unburned	Unburned	Brush/grass	Hatched
2	Burned	Unburned	Grass	Hatched
	Unburned	Unburned	Brush/grass	Abandoned
	Unburned	Burned	Cacti/grass	Abandoned
	Unburned	Unburned	Grass	Abandoned
	Burned	Unburned	Grass	Abandoned
	Burned	Unburned	Grass	Depredated
3	Burned	Burned	Brush/grass	Abandoned
	Unburned	Unburned	Cacti/grass	Abandoned
	Unburned	Unburned	Cacti/grass	Hatched
	Burned	Burned	Cacti/grass	Hatched
	Burned	Burned	Cacti/grass	Hatched
	Burned	Burned	Cacti/grass	Hatched
	Burned	Burned	Cacti/grass	Depredated

<sup>a</sup> Some locations were from burned areas but quail nested in the unburned “islands” of vegetation left by the mosaic burn pattern.

and feral cats were observed occasionally near trap sites.

Northern harriers and red-tailed hawks (*Buteo jamaicensis*) were probably responsible for most of the kills by raptors during this study. Jackson (1947) identified northern harriers as a major predator during winter months on bobwhites in the Rolling Plains of Texas. Cooper’s (*Accipiter cooperi*) and sharp-shinned hawks (*A. striatus*) may have also been responsible for some predation, but they were rarely observed at the study sites. Both Cooper’s and sharp-shinned hawks are known to be secretive, suggesting visual observation may not accurately represent their abundance. However, accipiter populations have increased across their range in the last 20 years (Sauer et al. 2000).

Radiomarking probably affects the short-term behavior and survival of bobwhites (Mueller 1986). Short-term mortality rates may be accelerated by radiomarking. However, Mueller et al. (1988) compared the mortality of radiomarked and unmarked bobwhites in northern Florida and found that high mortality rates occurred 40–45 days post marking, but mortality rates of unmarked bobwhites were similar.

Similar to Burger et al. (1995), we documented higher male mortality during the mating season. Burger et al. (1995) attributed higher male mortality during the breeding season to increased vulnerability of males to predators while displaying. Male bobwhites typically perch in an open area (e.g., a fencepost), while calling and may be increasing their vulnerability to predators, especially raptors. Raptors most noted for predation on bobwhites (i.e., accipiters and northern harriers) are winter residents in west Texas, and typically absent during the bobwhite breeding season in this area. Hernández (1999) reported similar survival for male and female bobwhites ( $\bar{x} = 72.2$  and 71.2 days, respectively) during the summer breeding period in Shackelford County, Texas.

The scale and intensity of the burns in this study may have minimized any potentially adverse impacts on survival. The best test of our hypothesis called for each treatment to burn uniformly to reduce any potential "island effects." However, such was not the case, as considerable patches of vegetation (herbaceous, cacti, and woody) remained following our burns. Such islands of unburned vegetation within burned areas may provide adequate refuges for bobwhites (Mueller et al. 1988). Post-burn monitoring of radiomarked bobwhites during this study supported the use of islands as refuge areas; radiomarked birds tended to be localized near areas that did not burn. If no "islands" were available, bobwhites moved off the burned area. The resulting mosaic burn patterns, particularly on site 1, may explain the lack of difference in survival among burned and unburned areas. Mosaic burns are the rule when burning rangelands in west Texas due to discontinuous fuel loads. Such "patchy" burns are desirable for quail (Guthery 1986:30).

#### Nesting Ecology

The importance of prickly pear as nesting habitat for bobwhites has not been documented prior to this study. In south Texas, Lehmann (1984:81) found only 1 of 189 bobwhite nests located in prickly pear. We observed 12 of 21 nests situated in cacti the summer immediately following burning. Carter (San Angelo State University, San Angelo, Texas, unpublished data) found that 8 of 12 scaled quail (*Callipepla squamata*) from study site 1 also nested in prickly pear.

In semi-arid regions with limited nesting cover, prickly pear may be more important in bobwhite nesting ecology than described previously. In a subsequent study in west Texas, Slater et al. (2001) placed simulated nests in either cacti-grass associations or grass alone, and found greater nest survival for nests in prickly pear at sites that provided <690 potential bunchgrass nesting clumps/ha. Hernández (1999) also confirmed the relative importance of prickly pear as a nesting substrate in Shackelford County, Texas. He reported that 30% of bobwhite nests were in prickly pear even on sites that had an abundance of traditional nesting substrate (>618 little bluestem plants/ha). Bobwhite nests situated in prickly pear had a hatch rate of 58% (14 of 24 hatched) but only 38% of nests in grass hatched (18 of 57 hatched).

#### MANAGEMENT IMPLICATIONS

Prescribed burning is often used to increase available forage species for livestock and simultaneously suppress undesirable species like prickly pear. For optimal prickly pear control, a prescribed burn is followed by herbicide application (e.g., picloram) that usually kills >95% of the cacti present (Ueckert et al. 1988). Landowners interested in maintaining quail nesting habitat should consider use of cactus for quail nesting sites in the semiarid Southwest. Burning could be used without the follow-up picloram application to reduce prickly pear by 20 to 50%, or herbicides could

be applied in a mosaic pattern to leave some cactus for nesting sites. Additional studies are needed to define optimum prickly pear and bunchgrass densities for increasing bobwhite nest survival.

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#### LITERATURE CITED

- Burger, L. W., Jr., M. R. Ryan, D. P. Jones, and A. P. Wywiakowski. 1991. Radio transmitters bias estimation movements and survival. *Journal of Wildlife Management* 55:693-697.
- Burger, L. W., Jr., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995. Seasonal and annual survival and cause-specific mortality of northern bobwhite in Missouri. *Journal of Wildlife Management* 59:401-410.
- Curtis, P. D., B. S. Mueller, P. D. Doerr, and C. F. Robinette. 1988. Seasonal survival of radio-marked northern bobwhite quail from hunted and non-hunted populations. *Biotelemetry X: International Radio-telemetry Symposium* 10:263-275.
- Day, G. I., S. D. Schemnitz, and R. D. Taber. 1980. Capturing and marking wild animals. Pages 61-88 in S.D. Schemnitz (ed.) *Wildlife Management Techniques Manual*. The Wildlife Society, Washington, D.C.
- DeVos, T. 1985. Predation and the bobwhite quail. *Quail Unlimited* 4:16-17.
- Dimmick, R. W. 1971. The influence of controlled burning on nesting patterns of bobwhite quail in west Tennessee. *Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies* 25:149-155.
- Ellis, J. A., W. P. Edwards, and K. D. Thomas. 1969. Responses of bobwhites to management in Illinois. *Journal of Wildlife Management* 33:749-762.
- Guthery, F. S. 1986. Beef, brush, and bobwhites: quail management in cattle country. Golden Banner Press, Corpus Christi, Texas.
- Guthery, F. S. 2000. On bobwhites. Texas A&M University Press, College Station.
- Heisey, D. M., and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. *Journal of Wildlife Management* 49:668-674.
- Hernández, F. 1999. The value of prickly pear cactus as nesting cover for northern bobwhite. Dissertation. Texas A&M University, College Station and Kingsville.
- Hernández, F., D. Rollins, and R. Cantu. 1997. Evaluating evidence to identify ground-nest predators in west Texas. *Wildlife Society Bulletin* 25:826-831.
- Hurst, G. A., L. W. Burger, Jr., and B. D. Leopold. 1996. Predation and galliforme recruitment: an old issue revisited. *Transactions North American Wildlife and Natural Resources Conference* 61:62-76.
- Jackson, A. S. 1947. A bobwhite quail irruption in northwest Texas lower plains terminated by predation. *Transactions North American Wildlife and Natural Resources Conference* 12:511-519.
- Kaplan, E. L., and P. Meir. 1958. Nonparametric estimation from

- incomplete observations. *Journal American Statisticians Association* 53:457–481.
- Kulowicz, T. 1989. SAS program for conducting log-rank tests of survival distributions from two trials analyzed using the Kaplan-Meier estimator program, STAGKAM. Missouri Department of Conservation, Columbia.
- Kurzejeski, E. W., L. D. Vangiler, and J. B. Lewis. 1987. Survival of wild turkey hens in northern Missouri. *Journal of Wildlife Management* 51:188–193.
- Lehmann, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M University Press, College Station.
- Mueller, B. S. 1986. Do radio tags have an effect on quail mortality? *Tall Timbers Report* 7:3–4.
- Mueller, B. S. 1988. Raptor effects on bobwhite quail. *Proceedings Southeast Raptor Management Symposium*, Blacksburg, Virginia.
- Mueller, B. S., and J. Atkinson. 1985. First year report: post-fire mortality study. *Proceedings Tall Timbers Game Bird Seminar*, Tall Timbers Research Station, Tallahassee, Florida.
- Mueller, B. S., J. B. Atkinson, Jr., and T. DeVos. 1988. Mortality of radio-tagged and unmarked northern bobwhite quail. *Proceedings 10th International Symposium on Biotelemetry*, Fayetteville, Arkansas.
- Pollock, C. M., S. R. Winterstein, and P. D. Curtis. 1989a. Survival analysis in telemetry studies: the staggered entry approach. *Journal of Wildlife Management* 53:7–14.
- Pollock, C. M., S. R. Winterstein, and M. J. Conroy. 1989b. Estimation and analysis of survival distributions for radio-tagged animals. *Biometrics* 45:99–109.
- Rollins, D., and J. P. Carroll. 2001. Predation impacts on northern bobwhite and scaled quail. *Wildlife Society Bulletin* 29: 39–51.
- Rosene, W. 1969. *The bobwhite quail: its life and management*. Rutgers University Press, New Brunswick, New Jersey.
- Sauer, J. R., J. E. Hines, I. Thomas, J. Fallon, and G. Gough. 2000. *The North American Breeding Bird Survey, Results and Analysis 1966–1999*. Version 98.1. United States Geological Service, Patuxent Wildlife Research Center, Laurel, Maryland.
- Seitz, W. K., and R. Q. Landers. 1972. Controlled burning in relation to bobwhite quail populations on a southern Iowa public hunting area. *Iowa State Journal of Research* 47: 149–165.
- Slater, S.C., D. Rollins, R. C. Dowler, and C. B. Scott. 2001. *Opuntia*: a prickly paradigm for quail managers in west Texas. *Wildlife Society Bulletin* 29:713–719.
- Speake, D. W. 1967. Effects of controlled burning on bobwhite quail populations and habitat on an experimental area in the Alabama Piedmont. *Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies* 20:19–32.
- Stoddard, H. L. 1931. *The bobwhite quail: its habits, preservation and increase*. Charles Scribner's Sons, New York.
- Tewes, M. E. 1984. Opportunistic feeding by white-tailed hawks at prescribed burns. *Wilson Bulletin* 96:135–136.
- Townsend, D. E., II, R. E. Masters, R. L. Lochmiller, D. M. Leslie, Jr., S. J. DeMaso, and A. D. Peoples. 2001. Characteristics of nest sites of northern bobwhites in western Oklahoma. *Journal of Range Management* 54:260–264.
- Ueckert, D. N., J. L. Peterson, R. L. Potter, J. D. Whipple, and M. W. Wagner. 1988. Managing pricklypear with herbicides and fire. Pages 10–15 in *Research Reports, Sheep and Goat, Wool and Mohair*. Texas Agricultural Experiment Station, San Angelo.
- United States Department of Agriculture. 1988. Standards and specifications for prescribed burning, Texas–Area 9. *Natural Resources Conservation Service, Field Office Technical Guide Set IV*, Washington, D.C.
- White, L. D., and C. W. Hanselka. 1989. *Prescribed range burning in Texas*. Texas Agricultural Extension Service Bulletin B-1310. College Station.
- Wright, H. A., and A. W. Bailey. 1982. *Fire ecology: United States and southern Canada*. John Wiley & Sons, New York.